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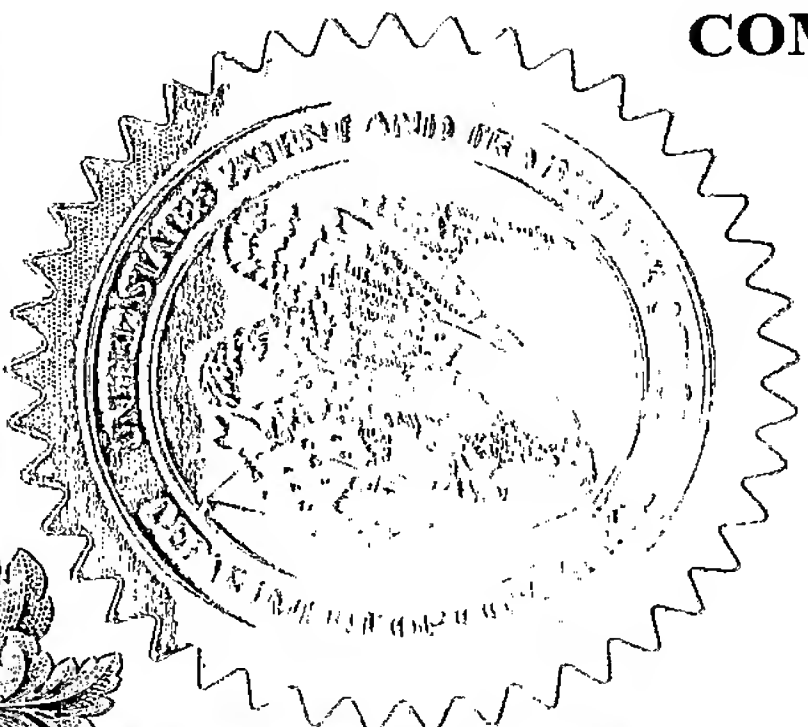
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N. WOODSON
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PROVISIONAL APPLICATION COVER SHEET

To the Commissioner of Patents and Trademarks
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This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(b)(2).

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TITLE OF THE INVENTION (280 characters max)

TILED OPTICAL FIBER DISPLAY

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ENCLOSED APPLICATION PARTS (check all that apply)

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METHOD OF PAYMENT (check one)

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UNITED STATES PROVISIONAL APPLICATION

Title: TILED OPTICAL FIBER DISPLAY

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TILED OPTICAL FIBER DISPLAY

FIELD OF THE INVENTION

5 The present invention relates to a tiled optical fiber display.

BACKGROUND OF THE INVENTION

Liquid crystal (LC), light emitting diode (LED) and plastic optical fibre (POF) technologies are combined in a unique way to form full colour displays.

10 Remarkable progress in LED technology has recently enabled high efficiency red, green and blue light sources with lifetimes of 100,000 hours. These are in current use for very large outdoor video displays (diagonal size of 20 ft, for example) with pixel spacings >2 cm, where the high cost of assembling from ~100,000 to ~1,000,000 LEDs is warranted. (Cost from \$50,000 to \$500,000 or more.)

15 For smaller displays, however, the required number of LEDs is still as high, and full colour LED displays having in the range from 1 mm to 10 mm pixel spacing are not cost-effective.

The publication "**Case Study: Building the Market for a Tiled-Display**
20 **Solution**", Needham, B., Information Display 10, pages 20-24, 2003, discloses an optical fiber-based display technology and application in public information displays and advertising. The publication "**Psychophysical Requirements for Seamless Tiled Large-Screen Displays**" Alphonse G A; Lubin J., Society for Information Display (SID) Digest, 49.1, pages 941-944, 1992, discusses the
25 optical requirements of a tiled display system to achieve a seamless appearance to the human observer. The publication entitled "**Optical Tiled AMLCD for Very**

Large Display Applications", Abileah A; Yaniv Z, Society for Information Display (SID) Digest, **49.2**, pages 945-949, 1992, describes an optical fiber module that may be used to enlarge the image size of a LC display enabling a tiled display. These publications do not disclose a means of avoiding colour filters to create full colour displays.

WO/03/067318 discloses a Tiled Display with Filter for Uniform Pixel Brightness which comprises an image display device having an array of electrically driven picture elements which are viewable at a viewing surface. Luminance corrections are arranged with respect to the image display device so as to apply a spatial luminance filter to the output of the image display device, the spatial luminance filter attenuating the light output by each picture element of the image display device in substantially inverse relation to the luminance response characteristics of the picture element so that each picture element exhibits substantially the same luminance for a given input electrical driving signal.

WO/03/067563 discloses a Display with Optical Fibre Face Plate which comprises an array of pixel elements; and an image guide having an array of light transmission guides, input ends of the light transmission guides being arranged to receive light from pixel elements of the image display device. Output ends of the light transmission guides provide an image output surface. Each light transmission guide includes a light-guiding region to promote light propagation by total internal reflection and a reflective coating on the light guiding region to promote specular reflection at the region-coating interface.

Therefore, it would be very advantageous to provide a tiled optical fiber display device structure in which the image size of a LCD display is expanded, enabling any desired number of LCD displays to be tiled together without gaps between them, so as to create a seamless picture, with superior display brightness and colour quality achieved due to backlighting by red, green and blue lamps and eliminating the need for light absorbing colour filters.

SUMMARY OF THE INVENTION

The present invention provides a tiled optical fiber display device structure which includes a light emitting diode (LED) backlit liquid crystal display (LCD). Light from the LCD enters an array of optical fibers that directs the light to a viewing screen. The optical fibers are arranged so as to eliminate the use of energy absorbing colour filters in conventional LCD's, and also to enable the seamless tiling of display modules.

The present invention provides a tiled optical display, comprising:
at least one display module including
i) a liquid crystal display and an array of light emitting diodes positioned to backlight the liquid crystal display, the array of light emitting diodes including at least one each of red, green and blue wavelength emitting light emitting diodes with a beam of light from each light emitting diode being focussed onto a pre-selected region of the liquid crystal display spaced from the light emitted by the other light emitting diodes, each pre-selected region of the liquid crystal display including an array of optical modulation elements such that light from each beam

of light passes through one set of corresponding optical modulation elements,
control means connected to each individual modulation element of each set of
optical modulation elements for controlling a desired amount of light from each
beam to pass through each individual optical modulation element of the liquid
5 crystal modulator; and

ii) a planar view plane having a pre-selected number of pixels, each
individual optical modulation element having a first end of an optical fiber
optically coupled thereto, and a second end of one optical fiber from each pre-
selected region of the liquid crystal modulator optically coupled to one of the pre-
10 selected number of pixels so each pixel is optically coupled to a red, green and
blue light emitting diode mediated by the liquid crystal modulator.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example only, reference
15 being had to the accompanying drawings, in which:

Figure 1 is schematic diagram of a tiled optical fiber display produced in
accordance with the present invention;

Figure 2 is a LED placement diagram, showing layout of 72 LEDs each
having two leads (all dimensions in mm), each LED only emits light having one of
20 three possible colours, namely red, green or blue, each triangle formed by three
neighbouring LEDs is comprised of a red, a green and a blue-emitting LED;

Figure 3 shows hole locations in a first optical fiber retaining plate for
through which the optical fibers are inserted;

Figure 4 shows hole locations in a second optical fiber retaining plate for through which the optical fibers are inserted;

Figure 5 shows an example of correspondence of holes in the first optical fiber retaining plate of Figure 3 with the holes in second optical fiber retaining plate. The left side of the Figure shows fiber locations of the first plate, and a right portion showing fiber locations of the second plate. For example, the three (3) fibers that end in the 3 locations of the second plate shown generally at 1 form a triangular pattern, and originate from the three locations, each shown as 1 in the first plate. Of the said three fibers, one is illuminated with green light, one with red and the other with blue.

DETAILED DESCRIPTION OF THE INVENTION

The structure and operation of the display will now be described with reference to Figure 1, which shows an example of a display 10 constructed in accordance with the present invention. A red, a green and a blue-emitting light emitting diode (LED) at 12, 14 and 16 respectively are supplied with a steady direct electric current (DC) to provide steady illumination. Focused LED's are preferred from which a light beam is emitted in a cone 18 of a particular colour from each LED with a typical divergence angle of $\sim 15^\circ$. Light from each LED 12, 14, and 16 illuminates only a desired portion 24, 26 and 28 respectively of a liquid crystal (LC) modulator 20 so that light of only one colour from only one LED

illuminates each associated portion of LC modulator 20. The LC modulator is comprised of both polarizers and polarization-rotating LC material capable of allowing varying amounts of light to pass through the LC modulator from substantially no light to a significant amount of light according to control voltages applied to the LC modulator.

These beamlets of light pass through a two dimensional array of modulator elements 30, with a corresponding set of optical modulation elements 30 situated to coincide with the intensely illuminated regions 24, 26 and 28 within LC modulator 20 such that light from each beamlet passes through one corresponding modulation element 30 and then exits from the LC modulator and enters an optical fiber element 34. Each modulator element may be individually controlled to allow a desired amount of light from each beamlet to pass through the LC modulator. One optical fiber element 34 is situated in front of each LC modulation element 30 such that it may collect one beamlet of light. The optical fiber elements 34 guide the light from the individual optical fibers and terminates at a flat viewing plane 40. Three fiber elements 34 carrying light from one blue, one green and one red beamlet, respectively, are grouped together at plane 40 to form one pixel shown at 42.

In the example of Figure 1, there are other pixels and optical fiber elements (e.g. fibers 34' and pixel 42') that are not fully shown, however, each pixel is formed from three optical fibers that are unique to the particular pixel, such that the three optical fibers are illuminated with red, green and blue light, respectively, obtained from corresponding LC modulator elements with the three

LC modulation elements 24, 26 and 28 being illuminated with light from the red-, green- and blue-emitting LED's, respectively.

The viewer at 50 observes the light exiting from the pixels 42, 42' and so on which are formed by the ends of the optical fiber elements 34, 34' and so on located at plane 40, and the viewer sees a pattern of light and dark pixels, depending upon the state of each modulator element 30 of modulator 20. Control of LC modulator elements 30, forms the desired displayed information in colour. Note that only three LED's have been necessary in total to illuminate a number of pixels, in the example of Figure 1, twelve (12) pixels.

Yet more pixels may be provided as indicated in Figure 1 on viewing plane 40 by additional optical fibers 60 which are lit by beamlets from other optical modulators, and other red, green and blue LED's. In this manner, as many pixels as desired may be formed on viewing plane 40, provided that a suitable number of LC modulators, LED's, and optical fibers are provided. An arbitrary number of units may therefore be tiled together from a number of LC light modulators and LED's to create as many pixels as desired.

A prototype display module has been constructed comprising seventy-two (72) LEDs (24 red, 24 green, 24 blue) arranged as shown in Figure 2 to illuminate a 2.5 inch diagonal active matrix LCD obtained from Optrex. Each cluster of three neighbouring LEDs in a triangular configuration includes one LED of each of the three colours. The LEDs have a 15 degree divergence of light.

The LCD is placed directly up against the LEDs and therefore light of one colour from a given LED does not mix with light from neighbouring LEDs, but

passes through the LCD and enters a first end of twelve (12) optical fibers that are arranged in a group in a circular pattern to efficiently utilize the light given off by the LED. Since each of the twelve (12) optical fibers is arranged in a symmetrical manner relative to the LED, it is illuminated with substantially the same intensity as the other eleven (11) fibers which access light from the same pre-selected region of the LCD 20. The arrangement of the optical fibers where light enters them at the first end is shown in Figure 3.

Each fiber now extends away from the LCD and being bendable, is routed to a series of locations from which light emerges from the second end as shown in Figure 4. Note that each fiber shown in Figure 4 corresponds to one fiber shown in Figure 3. There are 864 fibers. The two ends of each fiber are held in position by rigid plates about 2 mm in thickness. A first of the plates with holes located as in Figure 3 is at the first end of the optical fibers and a second of the plates with holes located as in Figure 4 is at the second end of the fibers. The fibers are orthogonal to the first and second plates where they pass through the plates, being guided by holes drilled normal to the plane of each plate, and the fibers are suitably bent as they pass between the plates which are about 3 cm apart. In plate 4, a 16 x 18 array of full colour pixels is realized, yielding a display area of dimensions 6.4 cm x 7.2.cm. It will be appreciated by those skilled in the art that the numbers of pixels, numbers of optical modulators, number of tiles, and dimensions of the various components making up the tiles disclosed herein are purely exemplary and are not intended to limit the invention in any way.

The correspondence between the holes in the two plates is partially shown, by way of example, in Figure 5. Figure 5 has two portions, a left portion showing fiber locations in the first plate, and a right portion showing fiber locations in the second plate. For example, the three (3) fibers that end in the three (3) locations of the second plate shown generally at 1 form a triangular pattern, and originate from the three locations, each shown as numeral 1 in the first plate. Of the three fibers, one is illuminated with green light, one with red and the other with blue.

In the present tiled optical fiber display which uses LEDs to backlight the LC modulator 20, light from modulator 29 is passed through specially woven fibres which form the pixels seen by the viewer. This structure permits the number of pixels to be much larger than the number of LEDs.

In the non-limiting tiled optical fiber display example constructed according to the present invention, four (4) full colour pixels are obtained for each LED. This represents a twelve (12) times reduction in LEDs, since twelve (12) full colour pixels require thirty-six (36) LEDs in conventional LED displays. Up to about one hundred (100) pixels can be achieved per LED for high resolution tiled optical fiber displays disclosed herein.

In a conventional LED display, high cost, high current drive electronics are required to turn LEDs on and off. In the present tiled optical fiber display, LED's are not modulated, and only low cost, low power LC drivers are needed. The present tiled optical fiber displays, unlike other LC displays, are not limited in viewing angle by the LED or the LC. This is due to the optical design of the

display. Viewing angles from small (30°) to large (160°) are available for all the present tiled optical fiber displays. Excellent contrast is achieved due to the black display screen. This is due to the light-absorbing faceplate and the high contrast LC modulator.

5 The present tiled optical fiber display system is also very advantageous in that it enables full colour outstanding colour saturation, long life ($\sim 100,000$ hours), high efficiency (6 lumens/watt), high brightness (400 cd/m^2), excellent contrast (sunlight viewing), shock-resistant screen (not glass), EMI compatible without shielding, pixel pitch from 2 mm to 10 mm and flexible display size small
10 (1-3'), medium (3-6') and large (6-20').

 The present tiled optical fiber display system is applicable to those areas of display technology which currently use LED and projection displays. Projection displays are not flat panels and are therefore restricted to applications that permit space for a screen and projector. Lamp life is limited, and regularly
15 scheduled lamp replacement is necessary. Contrast is only acceptable in low ambient light applications. A summary of key characteristics of LED, projection and technology of the present invention is shown in Table 1.

Table 1

Attribute	LED	Present tiled device	Projection
Size, feet diagonal	3-50	3-20	5-50
Resolution	10-30 mm pixel spacing	1-10 mm pixel spacing	1-10 mm
Flat	Yes	Yes	No
Cost/pixel	\$0.50	\$0.05	\$0.01
Sunlight-viewable	Yes	Yes	No
Life	100,000 hours	100,000 hours	5,000 hours for lamp replacement
Brightness	100 fL	100 fL	20 fL
Viewing angle	100°	Up to 160°	100°
Seamlessly tileable*	Yes	Yes	No

The present tiled optical fiber display system is modular. This means that small blocks (for example 5 cm x 25 cm) may be tiled together in a seamless manner to create the required display size. LED displays are also modular, however, projection displays show black lines where they are tiled together. The present tiled optical fiber display system therefore achieves a uniform appearance regardless of the number of modules used, and is therefore suitable for unusual size formats, for example, long, narrow banners (1' x 20') for overhead signage or architect- specified custom installations.

Glass-based technologies such as plasma, LCD, EL and CRT are not successful in formats over about 3-5 feet due to their high weight, high cost and fragile nature. These technologies are targeted at TV and smaller, public information displays only. They also suffer from lower operating lifetimes (10,000-30,000 hours) and lower power efficiencies (1-3 lumens/watt) which limits their suitability for high brightness, large size displays.

As used herein, the terms "comprises" and "comprising" are to be construed as being inclusive and open ended, and not exclusive. Specifically, when used in this specification including claims, the terms "comprises" and "comprising" and variations thereof mean the specified features, steps or components are included. These terms are not to be interpreted to exclude the presence of other features, steps or components.

The foregoing description of the preferred embodiments of the invention has been presented to illustrate the principles of the invention and not to limit the invention to the particular embodiment illustrated. It is intended that the scope of the invention be defined by all of the embodiments encompassed within the following claims.

THEREFORE WHAT IS CLAIMED IS:

1. A tiled optical display, comprising:

at least one display module including

i) a liquid crystal display and an array of light emitting diodes positioned to backlight the liquid crystal display, the array of light emitting diodes including at least one each of red, green and blue wavelength emitting light emitting diodes with a beam of light from each light emitting diode being focussed onto a pre-selected region of the liquid crystal display spaced from the light emitted by the other light emitting diodes, each pre-selected region of the liquid crystal display including an array of optical modulation elements such that light from each beam of light passes through one set of corresponding optical modulation elements, control means connected to each individual modulation element of each set of optical modulation elements for controlling a desired amount of light from each beam to pass through each individual optical modulation element of the liquid crystal modulator; and

ii) a planar view plane having a pre-selected number of pixels, each individual optical modulation element having a first end of an optical fiber optically coupled thereto, and a second end of one optical fiber from each pre-selected region of the liquid crystal modulator optically coupled to one of the pre-selected number of pixels so each pixel is optically coupled to a red, green and blue light emitting diode mediated by the liquid crystal modulator.

2. The tiled optical display according to claim 1 wherein the at least one display module is a plurality of display modules, the planar view plane of each display module being tiled together with a planar view plane of at least one other display module.
3. The tiled optical display according to claim 1 or 2 wherein each pre-selected region of the liquid crystal display having a beam of light from a light emitting diode focussed thereon includes a pre-selected number of optical fibers having their first ends optically coupled thereto, the first ends of the plurality of optical fibers being arranged symmetrically with respect to the beam of light focussed onto the pre-selected region of the liquid crystal display so that light transmitted by each optical fiber has substantially the same intensity, and wherein the second end of a given optical fiber of the pre-selected number of optical fibers is optically coupled to a different pixel than to which the second ends of the rest of the pre-selected number of optical fibers are optically coupled.
4. The tiled optical display according to claim 1, 2 or 3 wherein each light emitting diode is positioned close enough to the liquid crystal display so that the light beams from each light emitting diode does not interfere with the light beams from any other light emitting diode on the pre-selected areas of the liquid crystal display.

ABSTRACT

The present invention provides a tiled optical fiber display device structure which includes a light emitting diode (LED) backlit liquid crystal display (LCD). Light from the LCD enters an array of optical fibers that directs the light to a viewing screen. The optical fibers eliminate the use of energy absorbing colour filters in conventional LCD's, and also enable the seamless tiling of multiple display modules.

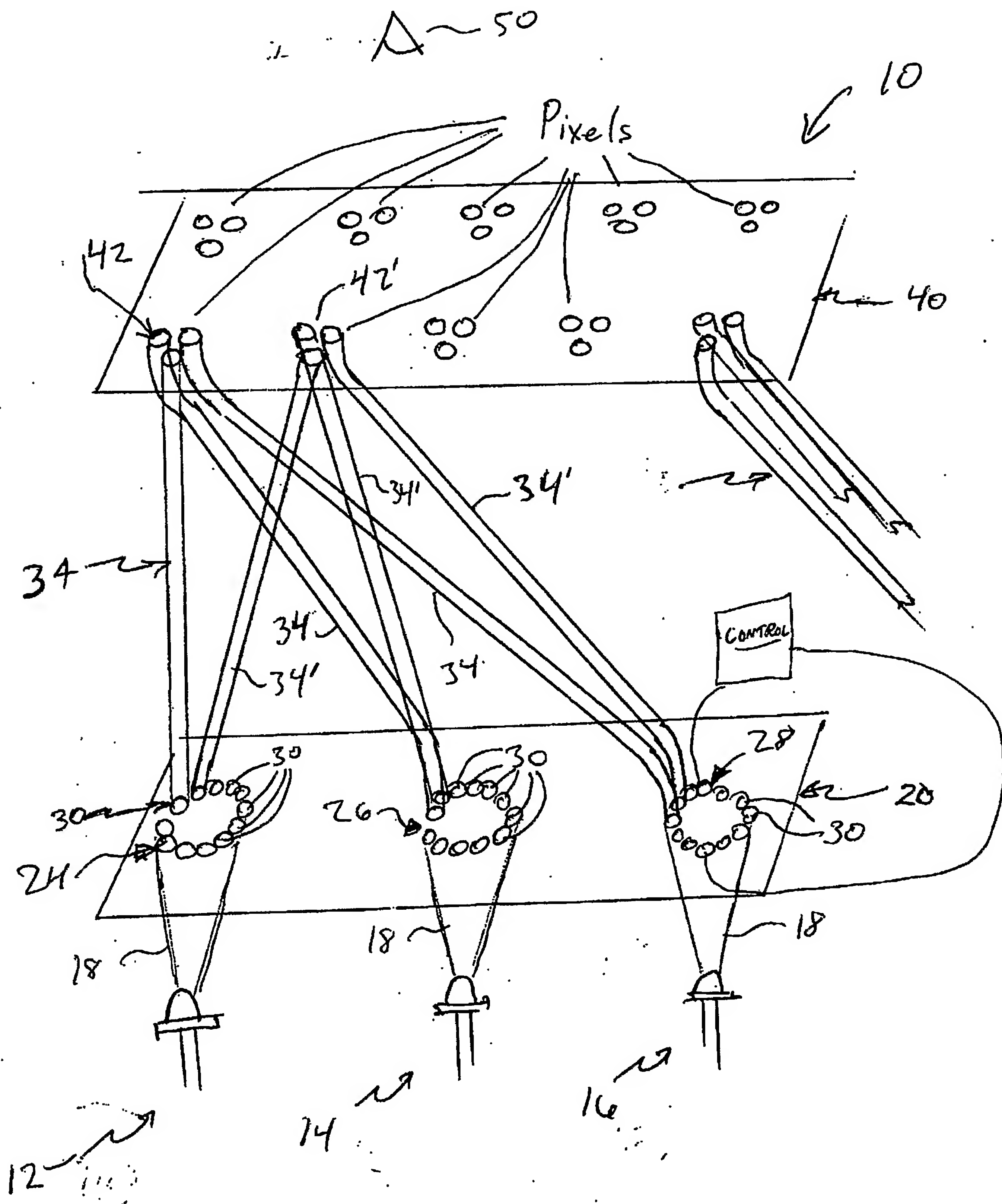


Figure 1.

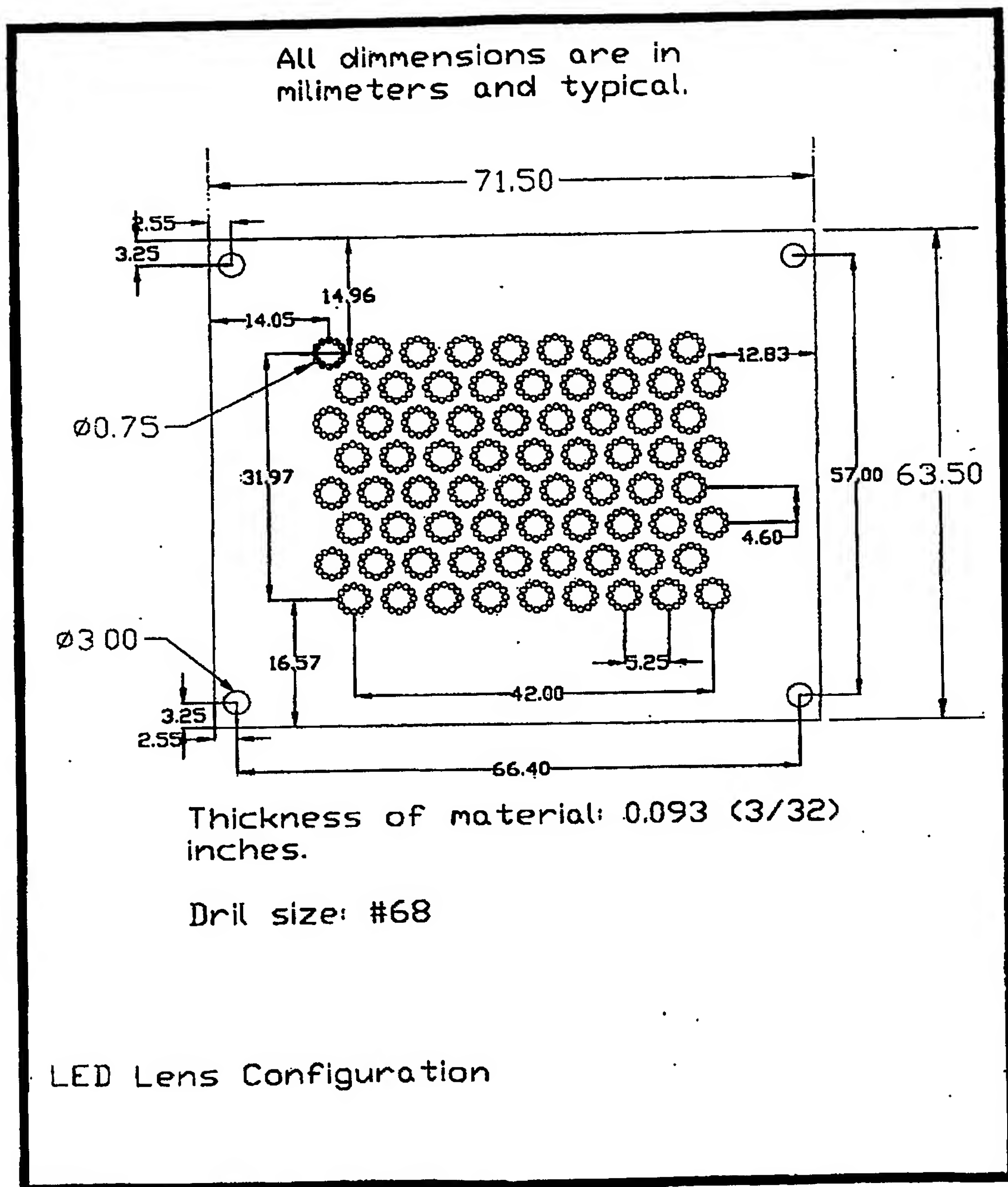


fig 3 showing hole locations in first plate.

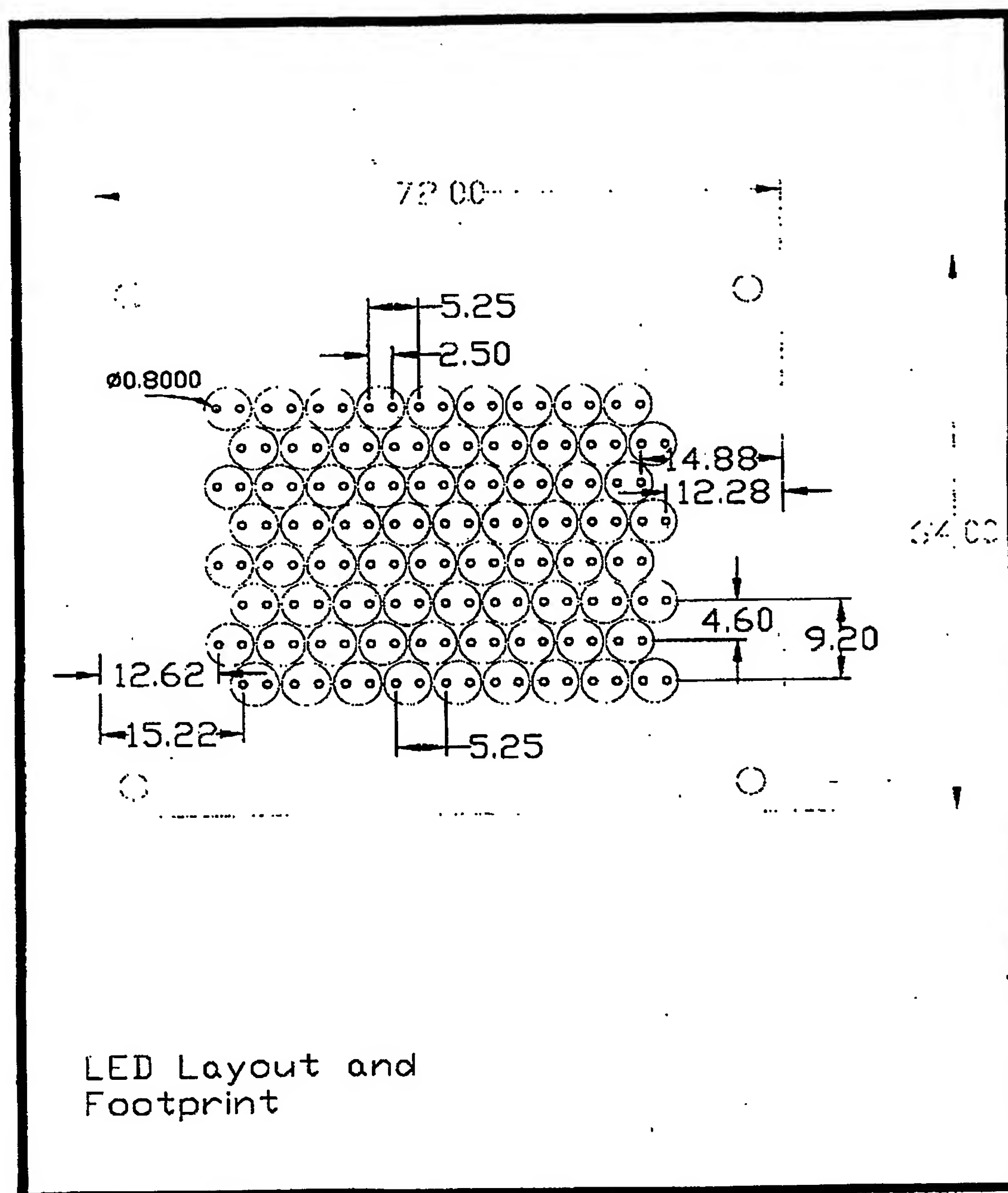


fig 2 LED placement, showing layout of 72 LEDs each having two leads. All dimensions in mm. Each LED only emits light having one of three possible colours, namely red, green or blue. Each triangle formed by three neighbouring LEDs is comprised of a red, a green and a blue-emitting LED.

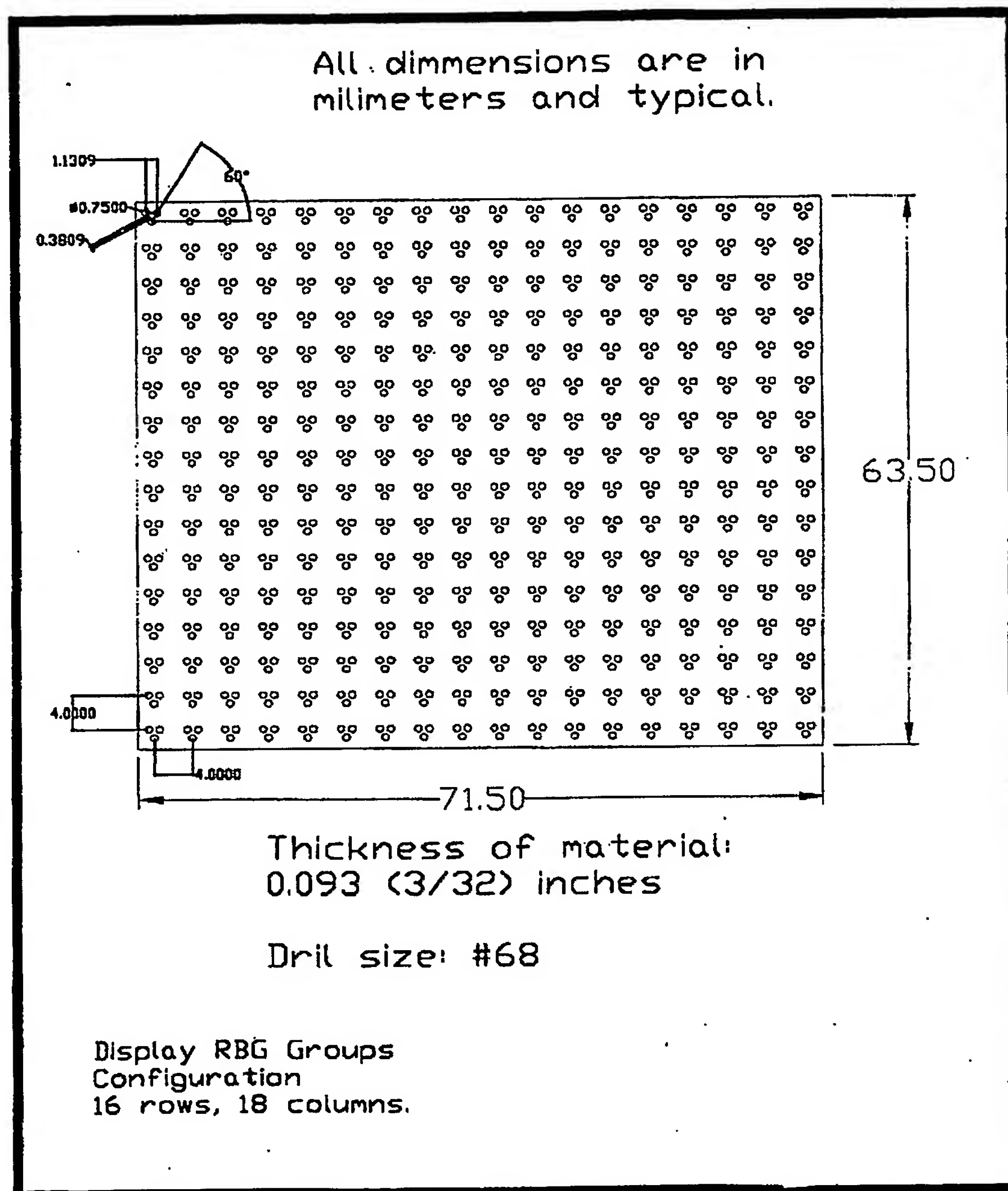


fig 4 showing hole locations in second plate



FRONT OF MACHINE

fig 5 Example of correspondence of holes in first plate with holes in second plate. The figure has two portions, a left portion showing fiber locations of the first plate, and a right portion showing fiber locations of the second plate. For example, the 3 fibers that end in the 3 locations of the second plate shown generally at 1 form a triangular pattern, and originate from the three locations, each shown as 1 in the first plate. Of the said three fibers, one is illuminated with green light, one with red light and one with blue light.